4. USE OF RETENTION FRACTIONS TO CALCULATE INTERNAL DOSE

4.1 An Example of Use for Inhalation of Class D I-131

The following example illustrates how IRFs may be used to interpret bioassay measurements. Additional examples of use of the IRF values for the evaluation of actual exposure cases are given in Appendix A.

A radiopharmicist was measured for I-131 in the thyroid on May 5, 1986 at the whole-body counter at a national laboratory. The measurement followed a routine area survey which occurred two days before and which revealed loose contamination in the radiopharmacy. The thyroid burden measurement and the subsequent discussion with the radiopharmicist indicated to the local safety representative and to a health physicist that an inhalation intake of 3.1 E+05 Bq (8.3 uCi) I-131 occurred on April 7, 1986, and that some additional I-131 was spattered about the work area. The thyroid dose equivalent was initially estimated to be 0.091 Sv (9.1 rem) and minor contamination was found on the radiopharmicist's car on May 6 and on his clothing on May 7, 1986. The type of whole-body counter used to measure thyroid activity was a single large NaI crystal which viewed the upper torso in addition to the thyroid.

The estimated thyroid dose equivalent exceeded the Department of Energy quarterly limit of 0.05 Sv (5 rem). On the other hand, it was less than the 0.5 Sv (50 rem) annual limit recommended by the International Commission on Radiological Protection (ICRP), and it was not in excess of the Department of Energy annual limit of 0.15 Sv (15 rem). However, it indicated inadequacies in the radiation protection program.

The work was planned to occur in a fume hood. Instead, this work was done in a laminar flow cabinet with an exhaust. The guide for laboratory workplace standards for dispersible radionuclides indicated to the safety representative that a more stringent workplace was required which in this case would have been a glove box since the radiopharmicist had no previous experience with I-131. Additionally, the April 7th work proceeded in a hurried manner and the radiopharmicist may have opened the vial containing I-131 in the room and not in the laminar cabinet, plus he added the wrong reagents.

The reagent error was corrected the following day but it was done by another person, who was unfamiliar with this work and it was done using new techniques, and was the likely cause of the spattered I-131. All persons associated with this work were subsequently checked for contamination but only the radiopharmicist was contaminated. Additionally, this work was repeated twice on April 22, 1986 in the laminar flow cabinet and the radiopharmicist did not

have contamination on his hands afterwards. However, all the April 22, 1986 work was performed according to written procedure and no errors were made.

The health physicist and safety representative recommended that the following interim steps be taken immediately but they were not listed in order of importance:

- All sealed vials with MBq (mCi) amounts of I-131 are to be refrigerated prior to opening, are to experience minimal exposure to light, and only be opened in a fume hood. Most of the procedure is to be performed in a fume hood and the procedure should be performed by trained personnel.

- The procedure should be written down, and if changed at a later time, then the safety representative should be informed. The written procedure should be reviewed and approved.

- A thin-window pancake Gieger-Muller instrument should be purchased and used in order to check for contamination. The radiopharmicist should be trained to monitor hands, clothing, and the work area following each work session. The instrument previously used was somewhat insensitive to beta, and his monitoring technique needed improvement.

Subsequent to the initial assessment by the safety representative and the health physicist, a formal investigation occurred. It was learned that the I-131 compound was a fatty acid and its distribution and retention were different from that chosen for the original dose assessment. Follow-up counting, with a multi-crystal whole-body counter, located 40% of the activity fixed in the heart and lung regions. Based on the new information, the I-131 intake was reassessed:

Table 4.1.1 Example of Intake Estimate for Iodine-131 Exposure Using Two Different Measuring Devices and Thyroid IRFs

Time After Accident, Days	Fraction of Intake Retained in Thyroid, IRF[a]	Thyroid Measurement Bq(μCi)	Estimated Intake, Bq(μCi)	Comment
28	0.0138	4.3 E+03 (0.115)	3.1 E+05 (8.3)	Single crystal torso detector, 100% in thyroid (assumed)
39	.00505	1.0 E+03 (0.0270)	2.0 E+05 (5.4)	Multi-crystal whole-body detector, 60% in thyroid (measured)

[a] Fractions obtained from interpolation of values in Appendix B, page B-103.

Because the intake could have occurred on April 22nd rather than April 7th, a urinary sample was taken on the day of the second whole-body count. The ratio of measured 24-hour urine activity to thyroid activity was 7.0 E-03. The ratio of 24-hour urine IRF to thyroid IRF on day 39 after the accident was 6.13 E-03. The IRFs for this ratio are obtained from interpolation of the values in Appendix B. If the accident occurred on April 22nd, the IRF ratio would be 4.9 E-03. Thus, April 7th appeared to be the day of intake. However, the metabolism of fatty acid I-131 has unknown impact on the IRF as used in this case, thus the events as described by the radiopharmacist are equally important in setting the date of exposure.

The DOE limit for organ dose equivalent for workers is in terms of quarterly and annual dose equivalent, thus the dose conversion factors, Sv/Bq (rem/μCi) inhaled, must be in terms of quarterly or annual dose equivalent per Bq (Ci) inhaled. For the thyroid, the limits are 0.05 Sv (5 rem) per quarter and 0.015 Sv (15 rem) per year. However, the half-life of I-131 is short compared to 13 weeks, thus the ICRP Publication 30 value for the committed thyroid dose equivalent per unit activity inhaled may be applied in order to estimate organ dose equivalent received in one quarter year:

$$2.0\ \text{E+05 Bq} \times \frac{2.9\ \text{E-07 Sv}}{\text{Bq inhaled}} = 5.8\ \text{E-02 Sv (5.8 rem) to thyroid}$$

The remaining activity, which was in the heart and lung regions, appeared to decay according to the 8.04 day half-life of I-131. It was assumed that this activity was distributed over a larger mass than that associated with the thyroid. Thus, the thyroid activity resulted in the largest organ dose equivalent. By assuming a weighting factor of 0.06, a mass of 332 grams and an estimated uptake of 1.9 E+04 Bq (0.52 μCi) for the heart, a weighted committed heart dose equivalent of 1.1 E-04 Sv (0.011 rem) is computed. Adding this value to the weighted thyroid dose equivalent, which is 1.7 E-03 Sv (0.17 rem) which is calculated by using a weight of 0.03 (ICRP77), yields a committed effective dose equivalent of 1.8 E-03 Sv (0.18 rem).

5. DESIGN AND CONDUCT OF A BIOASSAY PROGRAM

5.1 Derived Investigation Levels

To demonstrate how intake retention functions can be used for the design and conduct of a bioassay program, derived investigation levels have been calculated for 24-hour incremental urine samples. The levels were determined by multiplying values of the incremental urine intake-retention function by an investigation level based upon 5% ALI, or an investigation level based upon the ICRP Publication 26 recommendation of 0.3 x f x ALI, where f is the fraction of the year to which the monitoring applies. Values for an inhalation intake of Class W, 1 micrometer AMAD aerosols of 70.8 day ^{58}Co-58 are summarized in Table 5.1.1. The value for the ALI is 4 x 10^7 Bq (1.1x10^3 uCi), which is the stochastic value given in ICRP Publication 30 based upon consideration of limiting the risk from stochastic effects to that corresponding to a whole-body committed effective dose equivalent of 0.05 Sv (5 rem). Thus, the 5% ALI-based derived investigation level corresponds to a committed effective dose equivalent of 2.5 mSv (250 mrem) to the whole body of Reference Man. Monitoring is assumed to take place every t days post intake; thus, the fraction f of the year is calculated here by dividing the time t in days by 365 days. The daily frequencies of monitoring associated with small values of